

## TABLE OF CONTENTS

II	PC-0, PC-1, & PC-2 Design & Analysis Requirements .....	3
1.0	IBC Chapter 16 Structural Design .....	3
1.1	Section 1604 General Design Requirements.....	3
1.2	Section 1605 Load Combinations .....	3
1.2.1	1605.2 Load combinations using strength design or load and resistance factor design.....	3
1.2.2	1605.3 Load combinations using allowable stress design.....	4
1.3	Section 1606 Dead Loads .....	4
1.3.1	Add 1606.3 Future floor dead load. ....	4
1.4	Section 1607 Live Loads.....	4
1.4.1	1607.8 Impact Loads.....	4
1.4.2	1607.11 Roof loads .....	4
1.5	Section 1608 Snow Loads.....	4
1.6	Section 1609 Wind Loads.....	4
1.7	Section 1615 Earthquake Loads—Site Ground Motion .....	5
1.7.1	1615.1 General procedure for determining maximum considered earthquake and design spectral response accelerations. ....	5
1.8	Section 1616 Earthquake Loads—Criteria Selection .....	5
1.9	Section 1620 Earthquake Loads—Design, Detailing Requirements and Structural Component Load Effects .....	5
1.9.1	1620.4 Seismic Design Category D. ....	5
1.10	Section 1621 Architectural, Mechanical and Electrical Component Seismic.....	5
	Design Requirements .....	5
1.10.1	1621.1 Component design.....	5
1.11	Add Section 1624 Ice Loads. ....	5
1.12	Add Section 1625 Accidental Blast Loads.....	6
1.13	Add Section 1626 Minimum Antiterrorism Structural Design Measures.....	6
2.0	IBC Chapter 17 Structural Tests and Special Inspections .....	6
3.0	IBC Chapter 18 soils and foundations .....	6
3.1	Section 1805 Footings and Foundations .....	6
3.1.1	1805.4 Footings.....	6
4.0	IBC Chapter 19 Concrete.....	7
4.1	Section 1913 Anchorage to Concrete—Strength Design .....	7
5.0	IBC Chapter 20 Aluminum .....	8
5.1	No change. ....	8
6.0	IBC Chapter 21 Masonry .....	8
6.1	No change. ....	8
7.0	IBC Chapter 22 Steel .....	8
7.1	No change. ....	8
8.0	IBC Chapter 23 Wood .....	8
8.1	No change. ....	8

**RECORD OF REVISIONS**

<b>Rev</b>	<b>Date</b>	<b>Description</b>	<b>POC</b>	<b>OIC</b>
0	6/28/99	Initial issue in Facility Eng Manual.	Doug Volkman, <i>PM-2</i>	Dennis McLain, <i>FWO-FE</i>
1	2/09/04	Incorporated IBC & ASCE 7 in place of UBC 97; incorporated DOE-STD-1020-2002 versus 1994 and concepts from DOE O 420.1A; FEM became ESM, an OST.	Mike Salmon, <i>FWO-DECS</i>	Gurinder Grewal, <i>FWO-DO</i>
2	5/17/06	Major revision: Reduced commentary in favor of IBC 2003 amendments only; clarification of PC-0 applicability; OST became ISD.	Mike Salmon, <i>D-5</i>	Mitch Harris, <i>ENG-DO</i>

**Contact the Structural Standards POC**  
for upkeep, interpretation, and variance issues

<b>Ch. 5, Section II</b>	<a href="#"><u>Structural POC/Committee</u></a>
--------------------------	---

## II PC-0, PC-1, & PC-2 DESIGN & ANALYSIS REQUIREMENTS

- A. This Section provides the minimum requirements for the structural design and analysis of PC-0, PC-1, and PC-2 building structures, nonstructural components, and non-building structures at LANL, including programmatic equipment. Structural design procedure generally consists of the following:
- Establish structural arrangement/geometry
  - Establish loads and load combinations
  - Establish a complete load path for vertical and horizontal loads
  - Evaluate the structural response to the loads
  - Specification of structural capacity and drift limits (acceptance criteria)
  - Special design considerations, such as ductile detailing requirements
- B. Following the graded approach philosophy outlined in DOE Order 420.1A, “Facility Safety,” and implemented in guidance document DOE G 420.1-2 and design/evaluation standard DOE-STD-1020, PC-1 and PC-2 Structures, Systems, and Components (SSC) design, tests, inspections, observations, quality, and construction shall follow the provisions of the International Building Code (IBC; edition per ESM Chapter 1 Section Z10), Chapters 16 through 23, as amended below (amendments based on IBC 2003). PC-0 recognizes that for certain lightweight equipment items, furniture, etc, and for other special circumstances where there is little or no potential impact on safety, mission, or cost, design or evaluation for natural phenomena hazards may not be needed. Assignment of an SSC to PC-0 is intended to be consistent with, and not take exception to, model building code NPH provisions.
- C. Note that Chapter 6 – Mechanical, and Chapter 7 – Electrical, of this ESM also contain design requirements for many nonstructural components, and non-building structures.
- D. Loads listed in this Section shall be considered in the design of PC-0, PC-1, and PC-2 SSC. Criteria for assessment and mitigation for other natural phenomena loads listed in Appendix C of DOE G 420.1-2 are documented in “Design-Load Basis for LANL Structures, Systems, and Components,” LANL Report No. [LA-14165](#) [6]. This report [6] provides the basis for the loads, analysis procedures, and codes to be used in this Chapter.

### 1.0 IBC CHAPTER 16 STRUCTURAL DESIGN

#### 1.1 SECTION 1604 GENERAL DESIGN REQUIREMENTS

- A. **1604.5 Importance factors.** Add the following text:  
PC-0 SSC shall be Building Category I. PC-1 SSC shall be Building Category II. PC-2 SSC shall be Building Category IV.

#### 1.2 SECTION 1605 LOAD COMBINATIONS

##### 1.2.1 1605.2 Load combinations using strength design or load and resistance factor design

- A. **1605.2.2 Other loads.** Add the following text:  
Ice loads shall be considered in accordance with Section 2.3.4 of ASCE 7.

**1.2.2 1605.3 Load combinations using allowable stress design.****A. 1605.3.1 Basic load combinations.**

- **1605.3.1.2 Other loads.** Add the following text:  
Ice loads shall be considered in accordance with Section 2.4.3 of ASCE 7.

**B. 1605.3.2 Alternative basic load combinations.** Add the following text:  
The alternative basic load combinations shall not be used for anchorage design of SSCs.**1.3 SECTION 1606 DEAD LOADS****1.3.1 Add 1606.3 Future floor dead load.**

An allowance for a 10-psf future dead load in addition to project dead loads shall be included for the floors (not roofs) of new PC-1 and PC-2 buildings. However, this allowance shall not be used with equations 16-6, -11, -12, -18, and -20.

**1.4 SECTION 1607 LIVE LOADS****1.4.1 1607.8 Impact Loads.****A. Add 1607.8.3 Experimental explosion loads.**

1. Reactions from experimental explosion containment structures, due to explosions, shall be considered live loads.
2. External loads from experimental explosions shall be calculated in accordance with DoD TM 5-1300 and shall be considered live loads.

**1.4.2 1607.11 Roof loads****A. 1607.11.2 Minimum roof live loads.**

- **1607.11.2.1 Flat, pitched and curved roofs.** Substitute the following text:  
The minimum roof live load shall be taken as 30 psf for PC-1 and PC-2 buildings. The minimum roof live load shall not be reduced.

**1.5 SECTION 1608 SNOW LOADS****A. 1608.2 Ground snow loads.** Substitute the following text:  
The ground snow load shall be taken as 16 psf.**1.6 SECTION 1609 WIND LOADS****A. 1609.3 Basic wind speed.** Substitute the following text:  
The basic wind speed shall be taken as 90 mph (i.e., 3-second gust).**B. 1609.4 Exposure category.** Substitute the following text:  
The wind exposure category shall be taken as Exposure C.

**1.7 SECTION 1615 EARTHQUAKE LOADS—SITE GROUND MOTION****1.7.1 1615.1 General procedure for determining maximum considered earthquake and design spectral response accelerations.**

- A. **1615.1.3 Design spectral response acceleration parameters.** Substitute the following text:  
Five-percent damped design spectral response acceleration at short periods,  $S_{DS}$ , = 0.54 g, and at 1-second periods,  $S_{D1}$ , = 0.26 g.

**1.8 SECTION 1616 EARTHQUAKE LOADS—CRITERIA SELECTION**

- A. **1616.3 Determination of seismic design category.** Substitute the following text:  
The seismic design category shall be taken as Seismic Design Category D.

**1.9 SECTION 1620 EARTHQUAKE LOADS—DESIGN, DETAILING REQUIREMENTS AND STRUCTURAL COMPONENT LOAD EFFECTS****1.9.1 1620.4 Seismic Design Category D.**

- A. Add **1620.4.7 Foundations.**
1. Foundations shall not be designed in locations that are within 50 feet of known active faults. Hazardous waste treatment, storage and disposal facilities must not be located within 200 feet of a fault that has had displacement in Holocene time (the most recent time of Quaternary period, 11,000 years) regardless of their performance category per 40 CFR 264.
  2. To mitigate potential differential movements associated with surface faulting during the design-level earthquake, the design shall provide for a minimum horizontal and vertical differential movement between footings of ½ inch for PC-2 structures unless greater movement is indicated by geotechnical investigation.
  3. The perimeter basement walls, and other subterranean structural walls, shall be designed for soil pressures, including potential seismic loads, as recommended by a licensed geotechnical engineer knowledgeable of LANL soil conditions. An alternative for obtaining potential seismic loads is use of the Elastic Solution in ASCE 4 (para. 3.5.3.2).

**1.10 SECTION 1621 ARCHITECTURAL, MECHANICAL AND ELECTRICAL COMPONENT SEISMIC DESIGN REQUIREMENTS****1.10.1 1621.1 Component design.**

- A. Add **1621.1.5 ASCE 7, Section 9.6.1.6.6.** Modify ASCE 7, Section 9.6.1.6.6 to read as follows:  
The design strength of anchors in concrete shall be determined in accordance with the provisions of IBC Section 1913.

**1.11 Add SECTION 1624 ICE LOADS.**

Ice-sensitive structures, such as trussed towers, cable-supported structures, etc., shall consider the additional effects of ice loads in accordance with ASCE 7 Section 10.

**1.12 Add SECTION 1625 ACCIDENTAL BLAST LOADS.**

1. Permanent explosive facilities shall comply with TM 5-1300 and, as applicable, DoD UFC 3-340-01.
2. The design of all new facilities, or those with major modifications, shall conform to the DOE Explosives Safety Manual, DOE M 440.1-1A (or LLNL version; see LANS contract), requirements for either accidental explosions of explosives or vapor cloud explosions. Protective construction design features are provided in TM 5-1300 and DoD UFC 3-340-01. When evaluating for accidental blast load, AB, the loading AB shall replace E (earthquake) loads in the load combination equations. All potential blast effects shall be considered including blast overpressure, gas pressure, fragments, and ground shock.

**1.13 Add SECTION 1626 MINIMUM ANTITERRORISM STRUCTURAL DESIGN MEASURES.**

Structural design measures on progressive-collapse avoidance and window protection, presented in DoD UFC 4-010-01, shall be considered for those buildings where there is a credible terrorist threat. LANL shall specify whether these minimum antiterrorism measures are to be implemented; see also ESM Chapter 9, Facility Protection and Security.

**2.0 IBC CHAPTER 17 STRUCTURAL TESTS AND SPECIAL INSPECTIONS**

Refer to LANL ESM Chapter 1, Section Z10 and future ESM Chapter on building official and inspection for any modifications to IBC Chapter 17.

**3.0 IBC CHAPTER 18 SOILS AND FOUNDATIONS****3.1 SECTION 1805 FOOTINGS AND FOUNDATIONS****A. 1805.1 General.** Add the following text:

Permanent buildings and similar structures shall have a permanent foundation (e.g., full perimeter support, rodent-excluding, no trailer skirting, etc.). Permanent is defined in ESM Chapter 1, Section Z10<sup>1</sup>.

**3.1.1 1805.4 Footings.****A. 1805.4.2 Concrete footings**

- **1805.4.2.2 Footing Seismic ties.** Substitute the following text:  
Interconnect all spread-footing-type foundations using tie beams. The tie beam shall be capable of resisting, in tension or compression, a minimum horizontal force equal to 10% of the larger column vertical load. The tie beams shall also be capable of resisting bending due to prescribed differential settlements of the interconnected footings, as stipulated by the project geotechnical engineer.<sup>2</sup>

---

<sup>1</sup> LANL experience is that permanent foundations reduce O&M costs by minimizing settling that causes roof and structure cracks, excluding rodents and other pests, and improving energy efficiency by virtue of their superior insulation. Permanent is defined in ESM Chapter 1, Section Z10, as intended to be in place for 3 years or longer.

<sup>2</sup> LANL-specific requirement for conservatism.

## 4.0 IBC CHAPTER 19 CONCRETE

### 4.1 SECTION 1913 ANCHORAGE TO CONCRETE—STRENGTH DESIGN

- A. **1913.1 Scope.** Replace the second sentence with the following text:  
Headed bolts, headed studs, and hooked (J- or L-) bolts cast in concrete shall be designed in accordance with Appendix D of ACI 318. Post-installed (PI) anchors may be used in lieu of cast-in-place (CIP) anchors provided either 1913.2 or 1913.3 are met.
- B. **1913.2 Ductile PI anchors.** The strength of ductile PI anchors is governed by ductile yielding of a steel element.
- **1913.2.1 Ductile PI anchor applicability.** Either ductile PI anchors or CIP anchors shall be used for the following circumstances:
    1. Column anchorage for vertical bracing with a height greater than 12 feet.
    2. Fixed-base column anchorage for moment-resisting frames which are part of the seismic-force-resisting system.
    3. Any component, greater than 12-feet high, which transfers lateral seismic loads to the foundation.
 Ductile anchors may be used for any structure, system or component.
  - **1913.2.2 Ductile PI anchor criteria.** Ductile PI anchors shall be designed and evaluated in accordance with Appendix D of ACI 318, including paragraphs D.3.3.1 through D.3.3.5. For the purpose of applying Appendix D of ACI 318, LANL shall be taken as a region “of moderate or high seismic risk,” and all LANL structures are “assigned to intermediate or high seismic performance.”
- C. **1913.3 Brittle PI anchors<sup>3</sup>.** The strength of brittle PI anchors is governed by brittle behavior (i.e., tension or shear on a brittle steel element; concrete breakout, side-face blowout, pullout, or pryout). All anchors shall be assumed to have brittle behavior unless ductile behavior has been demonstrated by meeting Appendix D, paragraphs D.3.3.1 through D.3.3.5, of ACI 318.
- **1913.3.1 Brittle PI anchor applicability.** Brittle PI anchors shall not be used where ductile PI anchors are required.

<sup>3</sup> Ductile anchors are currently required by ACI 318 for structural members because seismic loads are assumed to be reduced for inelastic energy absorption. The requirement for ductile anchors is retained in these criteria for structural elements that are part of the seismic lateral load resisting system. While it is conservative to design equipment anchorage, component anchorage, etc. using ductile anchors, it is not always const effective. The brittle anchor criteria are developed to provide a safe, conservative, alternative design approach. The brittle anchor criteria are not applicable to components that are part of the structure’s lateral seismic load path. The brittle anchor modifications to ACI 318 code capacities,  $0.6/R_p$ , is intended to (1) remove the effects of the inelastic response modification factor,  $R_p$ ; and (2) provide a capacity similar to the brittle anchor criteria in ACI 349. The net effects of these criteria are that the brittle anchor will not fail below 167% of the design seismic load. Brittle anchor criteria are also provided for anchors using vendor catalog allowable capacities. Vendor catalog allowable capacities are usually based on the average (mean) ultimate capacity, determined by testing, divided by a factor-of-safety (FS). Use of 60% of the allowable capacity results in less than a 1% probability of failure for an FS=3 and coefficients-of-variation (COV) less than 0.67. It is judged that anchors with a COV greater than 0.67 will have a larger FS. Thus, it is judged that the brittle anchor criteria are sufficiently conservative. ACI 318-02 considers cracked concrete in anchor design, while previous codes wee often silent on the effects of cracked concrete on anchor strength. Vendor allowable capacities which do not consider cracking are multiplied by the factor  $\lambda=0.75$ , which is based on the guidance of DOE-EH-0545 for expansion anchors.

- **1913.3.2 Brittle PI anchor criteria.** The capacity of brittle PI anchors shall be developed from either 1 (strength design) or 2 (ASD):

$$1. \quad \text{Capacity} = \begin{cases} \frac{0.6}{R_p} \times \phi N_n \\ \frac{0.6}{R_p} \times \phi V_n \end{cases} \quad 2. \quad \text{Capacity} = \begin{cases} \frac{0.6\lambda}{R_p} \times N_{allowable} \\ \frac{0.6\lambda}{R_p} \times V_{allowable} \end{cases}$$

in which:

$\phi N_n$  and  $\phi V_n$  are calculated in accordance with Appendix D of ACI 318, excluding paragraph D.3.3.

$N_{allowable}$  and  $V_{allowable}$  are manufacturer's allowable working capacities, per an International Code Council Evaluation Service report (ICC-ES ER/ESR; <http://www.icc-es.org/>), based on the manufacturer's recommended factor of safety (FS). If  $FS < 4$ , then multiply allowable capacity by the ratio  $FS/4$ .

$\lambda = 0.75$ , unless (1) the manufacturer's allowable capacity includes the effects of cracked concrete, or (2) it can be demonstrated by calculation that the concrete will not crack for all applied loading combinations. If (1) or (2) apply,  $\lambda$  may be taken as 1.0.

$R_p$  is the Response Modification Coefficient used to develop the seismic loads, given as  $R$  in IBC Table 1617.6.2, or as  $R_p$  in IBC Sections 1621 and 1622.

## 5.0 IBC CHAPTER 20 ALUMINUM

5.1 No change.

## 6.0 IBC CHAPTER 21 MASONRY

6.1 No change.

## 7.0 IBC CHAPTER 22 STEEL

7.1 No change.

## 8.0 IBC CHAPTER 23 WOOD

8.1 No change.